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LUBRICANTS FOR IMPROVED GINNING AND SPINNING OF COTTON. A FRESH APPROACH TO FIBRE LENGTH PRESERVATION IN COTTON PROCESSING.

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Abstract

Feasibility trials conducted showed that the addition of lubricant helped preserve fibre length during lint cleaning. In laboratory trials three different lubricants (A, B and C) preserved fibre length in a fibre breakage assay based on a 'Shirley' Analyser. Measured fibre-to-metal co-efficient of friction values for each lubricant were significantly different with Lubricant B having the lowest fibre-to-metal friction values. It was on this basis and the extent to which fibre length was preserved in laboratory trials that Lubricant B was initially chosen for industrial trials in a gin. However, results from the industrial trials did not fit the laboratory model and Lubricant B produced a decrease in staple length and an increase in short fibre content when added in a commercial gin. A subsequent trial using Lubricant A, a lubricant that had a higher fibre-to-metal co-efficient of friction, resulted in improved staple length and reduced short fibre content on treated cotton. The reason for the difference between the two lubricants is thought to be due to a reaction, facilitated by the heat of the gin, between the emulsifiers present in Lubricant B with the protective cotton wax layer that surrounds each fibre. That Lubricant A was more successful raises questions about the complexity of the interactions between variables in the industrial situation and generates plenty of scope for further research. Lubricants were also added to cotton at the mill. Treated and untreated fibre from the gin trials was converted to fine count medium twist yarn. The effects of lubricant on fibre breakage during mill cleaning and carding, and on spinning performance and yarn quality were observed. The effect of lubricant in the mill on the particular cotton used in this trial was minimal although the addition of Lubricant A helped preserve fibre length during cleaning. The better length characteristics were generally reflected as better yarn properties, although yarn tenacity in treated samples was reduced.

Introduction

In today's world of high speed ginning, carding and spinning, the cotton fibre undergoes considerable stress in terms of fibre-to-metal interactions. A direct consequence of these interactions is the breaking of fibres resulting in shorter staple length, decreased length uniformity and increased short fibre content. Excessive fibre breakage leads to:

- Greater waste particularly at carding and combing processes.
- Greater hairiness and unevenness in yarn.
- Lower strength and elongation in yarn.
- Inability to sell into markets using new spinning systems that demand better fibre length uniformity.
- Reduced spinning efficiency.

In wool processing the addition of lubricants at carding has long been used to improve fibre length and decrease the percentage of noil (short fibre) produced. Haigh and Harrowfield (1990) further found that the properties of wool yarn are also beneficially affected by the use of lubricants, in addition to the improvement in fibre length. The present paper reports the results of studies examining the effects of adding small amounts of synthetic lubricant to cotton fibre prior to ginning, and prior to cleaning and carding in the mill.

Fibre breakage occurs at two stages during the ginning process:

- When fibre is separated from the seed at the gin saws.
- When fibre is cleaned in the lint cleaners post ginning.

Anthony and Griffin (2001) have shown that the force required to break a fibre is on average 1.8 times greater than the force required to extract it from the seedcoat although this is dependent upon variables such as moisture, field exposure and heat. Low moisture, exposure to sun, rain and microbial degradation in the field and high drying heat lead to increased fibre breakage in the gin. Of the variables moisture is critical in the maintenance of fibre length. It has long been established that fibre moisture content should be over 6% at the gin stand to maintain optimal length. Despite this recommendation it is common practice for cotton to be drier than this when it is ginned. The reason for this is that ginners are particularly sensitive to wet, or overly moist seed-cotton, because it reduces ginning efficiency and results in lower classing grades.

Lint cleaning, the process after ginning, is the stage where most fibre breakage occurs. Lint cleaners in gins are similar in action to the cleaners used in a spinning mill except that they are run at much higher throughputs. Lint cleaners are used in gins to remove excess trash (stem, seed-coat fragment, leaf etc etc.) from lint in order to improve the grade of the cotton (grade is based on colour and trash). However, there is growing debate as to whether this cleaning should be left to the cleaning machines in a spinning mill, which preserve fibre length. High performance cleaners in a spinning mill can process around 800 kg per hour while lint cleaners in a modern gin work at more than three times this rate - at 2500 kg per hour. While surface speeds can be greater in the spinning mill, e.g., card cylinder surface speeds are now in excess of 2400 m/min, it is the scrubbing of the fibre batt between the lint cleaner cylinder and grid bars that is central to the fibre breakage problem. Fibres are compressed into a thick, dense batt by feed and doffing rollers (see Figure 1), leaving them more difficult to comb out and more likely to be broken by the combing action of the saw tooth wire cylinder, the surface speed of which can be as fast as 1700 m/min.

Methodology

Trial Format

The format for the project was as follows:

1. Laboratory scale lubricant selection trials
2. Industrial ginning trials
3. Industrial spinning trials

Lubricant Selection Trials

Three lubricants (A, B and C) provided by Cognis Deutschland GmbH for this study were screened in laboratory trials using a fibre breakage assay and fibre-to-metal friction measurements. These results were then used to choose one of the lubricants for an industrial scale trial in a gin. Lubricants A and B are blended mixtures containing vegetable oils, emulsifiers and antistatic agents while Lubricant C is a detergent.

Fibre Breakage Assay

Lubricant treated seed-cotton samples (irrigated *Gossypium Hirsutum* cv. Sicala 40) were ginned using a twenty-saw laboratory gin. Ginned samples were then cleaned using a 'Shirley' Analyser in order to examine the effect that lubricants have on fibre breakage during cleaning. Figure 2 shows the effect of successive passages in a 'Shirley' Analyser on the length properties of untreated cotton. The relationship shown corresponds with the effects seen in commercial gins when successive lint cleaners are used. Lubricants were applied to one kilogram of seed-cotton laid evenly over a 0.5 m^2 area. Four dosages were investigated: 0.1% w/w, 0.2% w/w, 0.4% w/w and 0.6% w/w. Lubricants were applied neat using a gravity fed pressurized spray gun in a series of spray bursts. Samples were ginned straight away with a conditioning sample preceding the ginning of the sample from which fibre property results were collected. Treatments were applied on weight of seed-cotton in order from lightest (0.1% w/w) through to the heaviest (0.6% w/w) dose. The gin was cleaned between lubricants with two kilograms of non-lubricated seed-cotton. Fibre regains and test conditions were consistent amongst the trials. Length characteristics of ginned and cleaned samples were tested on a HVI Fibrograph.

Fibre-to-Metal Friction Measurements

Fibre-to-metal friction was measured by adapting the capstan method described by Eley et al (1985). The metal test surface used in this method is a 5 mm diameter stainless steel spindle cylinder that was prepared to a consistent surface roughness with 600-grade emery paper. A single fibre is put under tension (250 mg) over the spindle cylinder that is prepared with the lubricant being tested. Tension is measured between the end of the measuring cantilever and the affixed mass as the spindle rotates at 1500 rpm. Each lubricant is prepared for application by dilution in methylene chloride at one part active matter in 320 by volume. This solution is then applied to the cleaned surface. Prior to application the metal surface of the spindle was cleaned with Decon, a glassware detergent, and then rinsed with hot water. This was followed by two rinses in a 1:1 mixture of isopropanol and methylene chloride. Measurements were performed in standard conditions, i.e., 20°C and 65% relative humidity, on ten long fibres (> 30mm) selected at random from a combed staple bundle.

Ginning Trials

The objective was to see whether the outcomes of the lubricant selection trials could be replicated in an industrial situation, i.e., in a commercial gin. Lubricant B was used initially but was replaced with Lubricant A upon analysis of high volume instrumentation (HVI) results from the first trial.

The gin trials were conducted in a three-stand Lummus built saw-gin that typically processes spindle-harvested cotton requiring minimal cleaning (see Figure 3). Spray nozzles from three pumps delivered atomised lubricant neat into three ducts taking dried seed-cotton from the drying tower to pre-gin cleaners and onto the gin saws. The pumps were set to deliver lubricant at 0.1% on weight of seed-cotton. Three modules (around 45 tonnes) of seed-cotton were treated with lubricant in each trial.

The seed-cotton used in the trial came from successive modules of Sicala 40 cotton grown under irrigation in south-west NSW. Modules from the same property were used in both lubricant trials. Cotton was ginned using normal heat and cleaning settings, i.e., 70°C drying heat and two-lint cleaners.

In both trials the HVI properties of bales from the three treated modules and at least three untreated modules ginned before and after the treated modules were analysed.

Fibre samples from the second gin trial (Lubricant A) were also tested for fibre-to-metal friction. In this case the spindle cylinder was conditioned by rubbing it with a bundle of sample fibres before testing. Otherwise preparation of the instrument for testing was as described earlier.

Spinning Trials

Treated and untreated cotton from the gin trial was obtained and spun to yarn. Two bales of untreated cotton and one bale of Lubricant A treated cotton were collected from the gin trials to assess the effect of lubricant upon fibre and yarn quality in the mill. Each bale (210 kilograms) was split into three lots each approximating 70 kilograms and subject to different lubricant treatment at the bale laydown. Figure 4 illustrates the treatments applied to each lot.

Each lubricant treatment was processed through a pilot opening and cleaning plant. The pilot plant equipment is Trützschler made and comprises a Blendomat, MS Reserve Hopper, four-chamber Multimixer, RSK1200 (cleaner), FBK Tuft Feeder and DK 740 card. Lint samples were taken pre-cleaner, post cleaner, pre-card and post card. Samples were tested using an Advanced Fibre Information System (AFIS) instrument for length, nep and trash content and distribution and on a Micro-Dust and Trash Analyser (MDTA) for trash, dust and fibre fragments.

Card sliver was processed to roving via two drawings and spun into medium twist ($\alpha_e = 3.8$) Nec 30/1 yarn on a Rieter ring frame. Yarn samples were tested for evenness, imperfections, tenacity, hairiness and friction.

Results and Discussion

Lubricant Selection Trials

Figures 5(a) to (c) show that each of the lubricants protected the staple length of lint samples processed through two passages of the 'Shirley' Analyser. It is noted at the outset that samples not subject to cleaning in the 'Shirley' Analyser, i.e., not subject to lint cleaning, had better length properties, although this effect generally diminished with the addition of lubricant. There is a thought at this point that the addition of lubricant might therefore be more beneficial after ginning but before lint cleaning.

Lint samples subject to two 'Shirley' passages benefited from the addition of lubricant. Benefit in this context is defined as the extent to which staple length is protected. Benefits, however, were also reflected in terms of better length uniformity and lower short fibre indices. Lubricants A and C showed the best protection with lightest add-ons whilst Lubricant B gave similar protection with a larger add-on. The protection afforded by all lubricants increased step-wise to 0.4% w/w. After this point heavier applications of Lubricants A and C caused increased fibre breakage while additional applications of Lubricant B resulted in further fibre protection. It was noted that seed-cotton would generally slip against the seed roll conveyor when lubricant add-ons exceeded 0.4% w/w. Results showed that dry, untreated cotton produced the best length properties after ginning and that samples treated with higher lubricant add-ons generally had worse length properties.

Fibre-to-metal friction coefficients were also measured (see Table 1). Lubricant B produced the lowest fibre-to-metal coefficient of friction while Lubricants A and C had relatively high coefficients of friction, and in both cases fibres broke during testing. Eley et al (1985) found that in wool processing the addition of a lubricant with the lowest fibre-to-metal coefficient of friction at carding improved fibre length and decreased the percentage of noil (short fibre) produced. Thus, it was on this basis that Lubricant B was initially chosen for the industrial gin trial.

Ginning Trial

The effect of applying Lubricant B to high quality seed-cotton was to reduce staple length (see Figure 6) dramatically. Fibre strength was also reduced in the treated cotton although other fibre properties were unaffected by the addition of the lubricant (see Table 2). The effect of Lubricant B, under gin conditions, on fibre length was immediate suggesting that the lubricant did not coat or condition the gin metal surfaces. Furthermore, the immediacy of the effect suggests that the seed-cotton was affected near the point lubricant was added to the fibre, i.e., near the drying tower. While exact details of Lubricant B's chemical make-up are proprietary it is believed a combination of high temperature, the air temperature near the drying tower was in excess of 60^{0}C, and the higher levels of emulsifier in its blend assisted in removing, or reducing the effectiveness of, the protective wax layer that envelopes a cotton fibre.

The same trial set-up was applied using Lubricant A with the only significant difference being that the seed-cotton to be ginned was one month older and consequently had been exposed to more microbial (fungal) damage. This was reflected in the reduction of its USDA grade from a strict middling (11/21) type to a middling (21/31) type with light spot (see Table 2). Microbial damage was also reflected by an increase in micronaire and a decrease in fibre length parameters. Application of Lubricant A to this cotton at the same rate as Lubricant B improved staple length and reduced short fibre content although this improvement was gradual and not seen until the third module was being processed. This, and the fact that staple length remained high after the sprays had been turned off, suggested that a period was required before gin surfaces were conditioned and the lubricant could work. The improvement in staple length over the last part of the third module was approximately 1/32nd (see Figure 7) and there was a corresponding decrease in short fibre content of 15 percent. All other properties remained constant for both treated and untreated.

Fibre-to-metal friction tests on treated and untreated fibre showed that the addition of lubricants tended to increase the fibre-to-metal co-efficient of friction (see Table 3), although these tests were performed at standard conditions and not at 60°C, the temperature at which the seed-cotton was treated with the lubricant. It is known that cotton waxes melt at around 70°C (ref) but it is not known what effect the addition of the applied lubricants have on the chemical structure of the fibre surface under elevated temperatures. The increased fibre-to-metal co-efficient of friction suggests a permanent change in the chemistry of the cotton fibre wax layer as a result of the addition of lubricant.

The fibre-to-metal co-efficient of friction results also show that the lubricant treatments were well distributed. The results represent a small sample (10 fibres) of fibre yet the differences in the co-efficient of friction between untreated and treated samples are statistically significant.

Spinning Trial

Fibre samples taken at cleaning and carding points showed only small differences in average length and short fibre content between untreated cotton and cotton treated with 0.1% (owf) lubricant. The length properties of cotton treated with 0.03% lubricant generally lay between those of untreated and 0.1% treated cotton. Generally, the addition of Lubricant A improved average length of the fibre in card sliver, even when added on top of a 0.1% gin application, although the biggest difference between untreated and 0.1% treated card sliver fibre was only just significant at the 5% level and amounted to an increase in average length of less than 0.3 mm. Conversely, Lubricant B reduced average fibre length (see Figures 8(a), (b) and (c)).

Nep and trash levels in lubricant treated card sliver were higher than in untreated sliver although the differences were small and differences between treated and untreated fibre at other stages of processing were inconsistent.

Processing performance, i.e., ease of web transfer in carding, sliver breakages, etc etc., was no different between untreated and treated fibre although it was noted that add-ons of 0.1% appeared to reduce fly and in the case of Lubricant A there was initial difficulty in drawing the card web off the doffer into the condenser rollers.

All rovings processed well with no lapping problems and no noticeable difference in spinning performance. Except for the first untreated sample (Bale 1), which was processed through to yarn within the week, samples were drawn and then stored for 2 weeks in draw-cans before being converted into roving and yarn immediately after. Approximately 10 kilograms of yarn from each treatment was spun with the yarn properties of six one-kilogram packages being tested.

The yarn property results are somewhat puzzling as they generally portray lubricant treated cotton as having worse properties than untreated cotton. In the main, the properties of yarn reflect the quality of the fibre from which they are spun however in these results longer staple fibre, e.g., from Lubricant A treated cotton, did not translate necessarily into higher tenacity yarn. Table 4 lists the yarn properties (tenacity, elongation, evenness, imperfections and hairiness) for each treatment. The results show that the addition of Lubricant B affected all yarn properties measured negatively except for yarn friction. The addition of Lubricant A also affected yarn properties although to a lesser degree and not all negatively as was the case with the B. In particular, the bale of cotton treated in the gin with Lubricant A produced the most even and least hairy yarn. This was in spite of having been stored as seed-cotton in the gin yard for a month longer than the seed-cotton ginned to produce bales 1 and 2 (see Table 1). The treatment of this bale with more lubricant, i.e., an additional 0.03% and 0.1% of Lubricant A, improved yarn evenness, imperfection levels and hairiness.

Conclusions

Results from this trial show that the addition of small amounts of certain lubricants can preserve fibre length during mechanical cleaning, although the interactions between the lubricant, the outer waxy layer of the cotton fibre and physical conditions in the gin or mill, e.g., the heat used for drying in the gin, are complex and variable. It is noted here that the cotton used in this study was high quality and that the differences seen here might have been more positive had the cotton been a lower grade and subject to a greater degree of weathering or microbial damage. Certainly, the lowest grade cotton used in this study benefited from the addition of lubricant in terms of the yarn quality spun from it, i.e., the yarn was more even and had reduced hairiness.

The application of lubricant can also have detrimental effects upon the fibre and its processing ability. Lubricant ingredients should not be miscible with the layer of wax that protects the fibre against fibre-to-metal interactions. As well, the addition of excessive amounts of lubricant, i.e., greater than 0.16% owf or 0.4% on weight of seed-cotton, will cause fibres in to stick together and expose them to increased action of the gin saws or saw-toothed cylinder.

The study has presented some early results that indicate lubricants have a place in the processing of cotton, particularly in the ginning of cotton. However, much remains to be uncovered with regards to the interaction of lubricant chemistry with the surface chemistry of the cotton fibre and conditions in the gin and mill.

Acknowledgements

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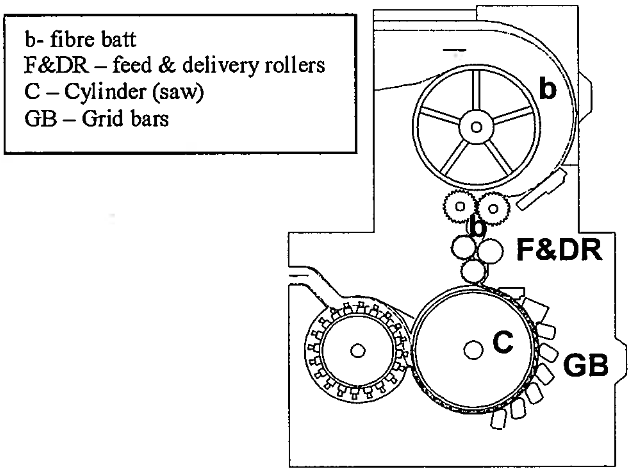


Figure 1. Flow of cotton through lint cleaner (from Continental Eagle)

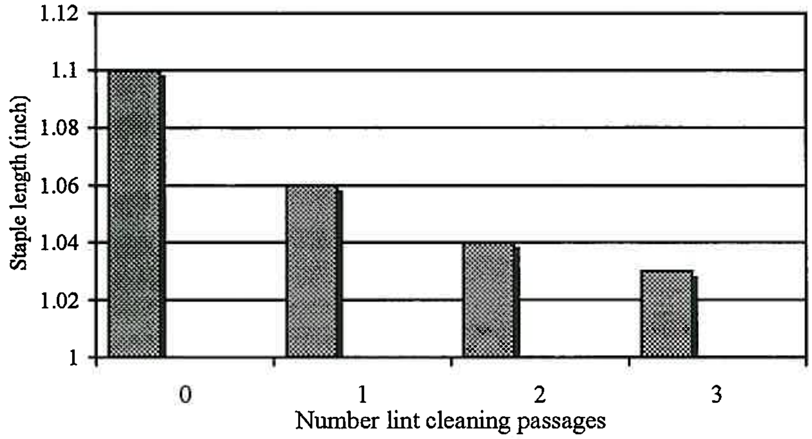


Figure 2. Effect of lint cleaning ('Shirley' Analysing) on staple length

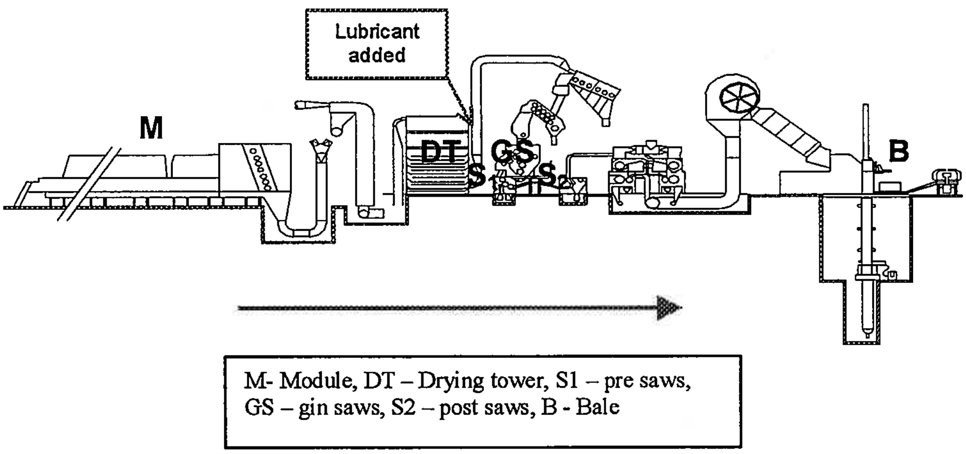


Figure 3. Gin set-up and treatment and sampling points during trial

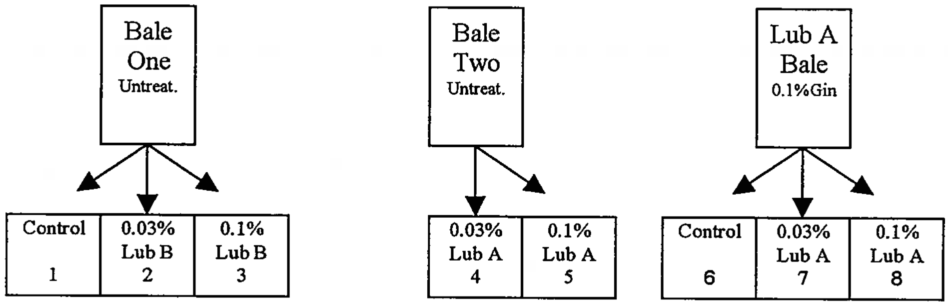


Figure 4. Mill lubricant treatments

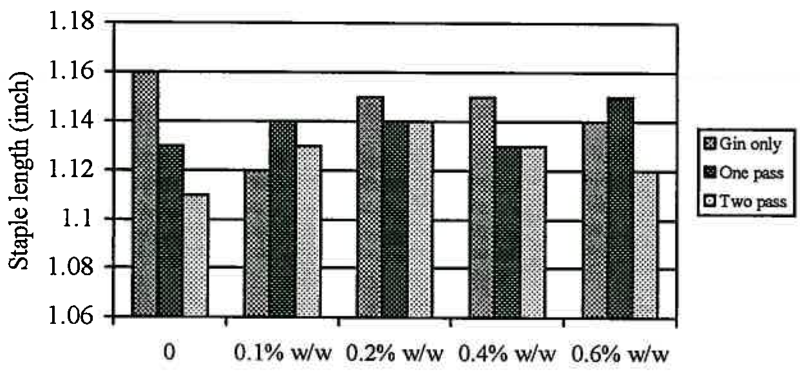
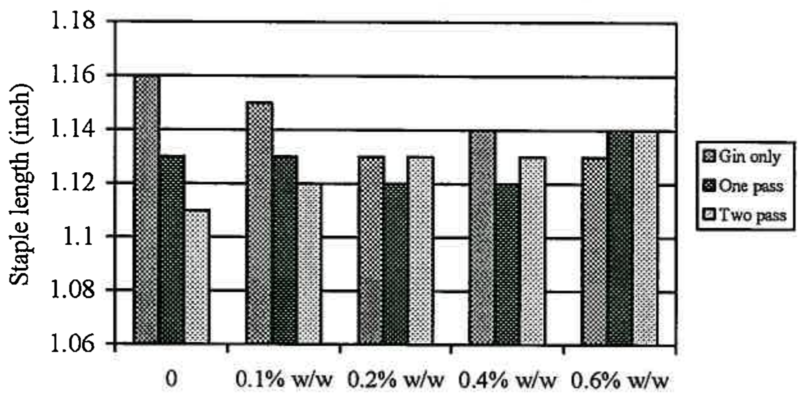


Figure 5(a). Effect of Lubricant A add-ons on staple length



5(b). Effect of Lubricant B add-ons on staple length

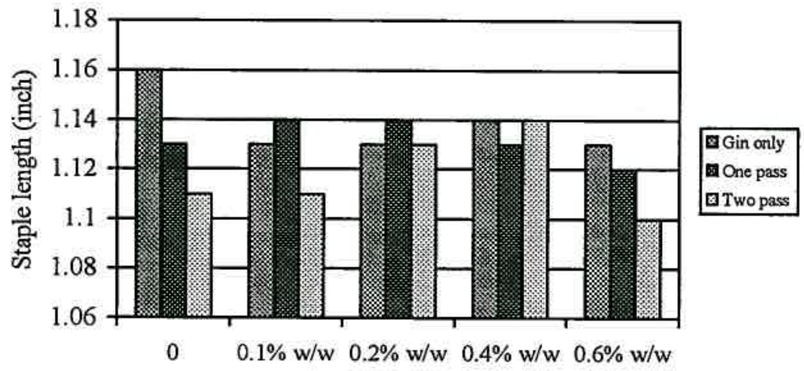


Figure 5(c). Effect of Lubricant C add-ons on staple length

Table 1. Fibre-to-metal coefficients of friction

Lubricant	**Average Coefficient of Friction**	**Std. Dev. of Co-Efficient of Friction**
Lubricant B	0.216	0.054
Lubricant A	0.610	0.116
Lubricant C	0.540	0.034
Control	0.679	0.050

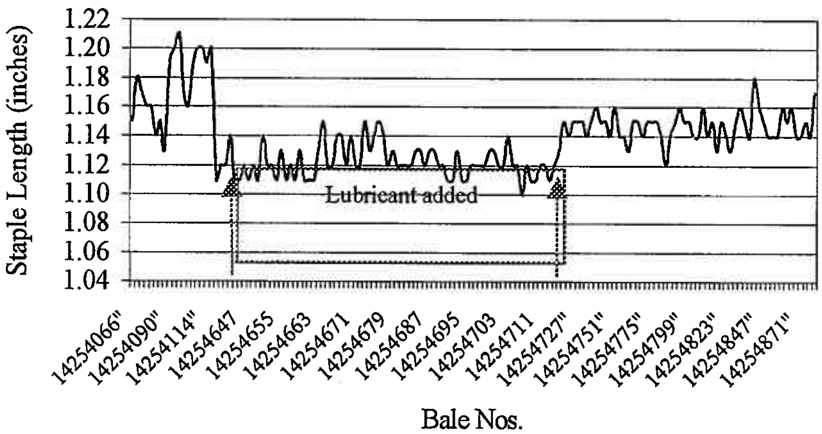


Figure 6. Effect of Lubricant B on staple length

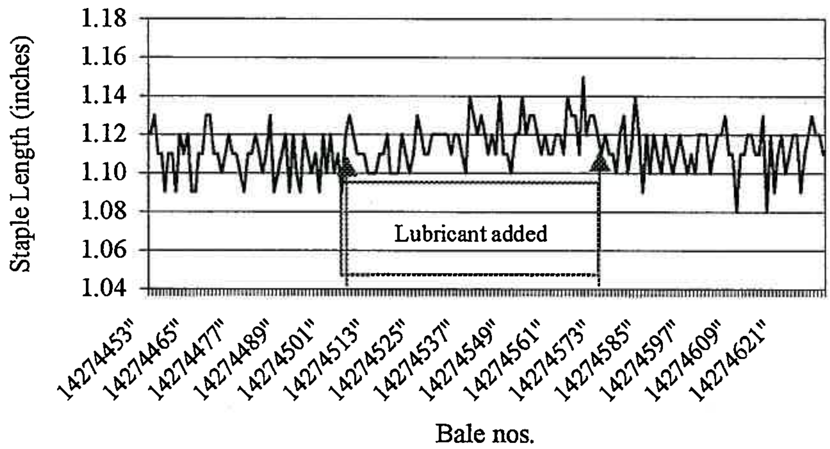


Figure 7. Effect of Lubricant A on staple length

Table 2. HVI properties of treated and untreated lint from gin trials

HVI Property	Lubricant B treated	Lubricant B untreated[1]	Lubricant A treated	Lubricant A untreated[2]
Grade	11.2/21.1	11.2/21.1	21.2/31.1	21.2/31.1
Micronaire	4.4	4.4	4.6	4.6
Strength	28.7	31.6	31.4	31.4
Elongation	9.0	8.7	7.9	7.9
Length	1.12	1.15	1.12	1.11
Uniformity	82.3	83.1	83.6	83.5
SFI	6.2	4.1	5.9	7.7

1. HVI properties after treatment
2. HVI properties before treatment

Table 3. Fibre-to-metal friction values on ginned lint samples – before and during lubricant treatment

Treatment	Average Co-efficient of Friction	Std. Dev. of Co-efficient of Friction
Before - Lub A	0.364	0.064
During - Lub A	0.538	0.122
After - Lub A	0.447	0.053
Before - Lub B	0.369	0.011
During - Lub B	0.456	0.104

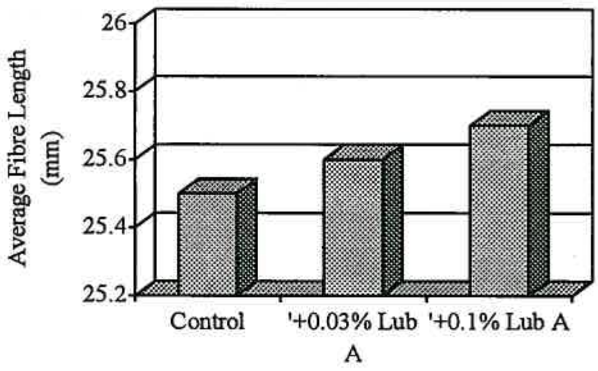


Figure 8(a). Effect of Lubricant A on average fibre length in card sliver

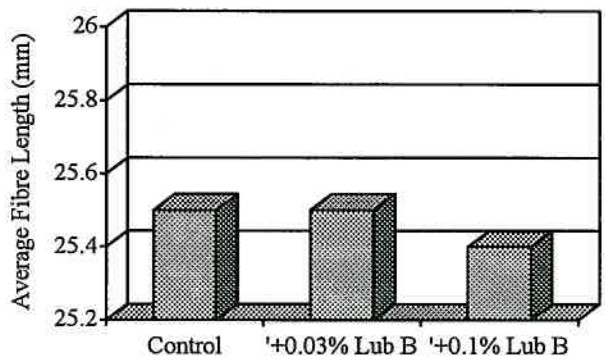


Figure 8(b). Effect of Lubricant B on average fibre length in card sliver

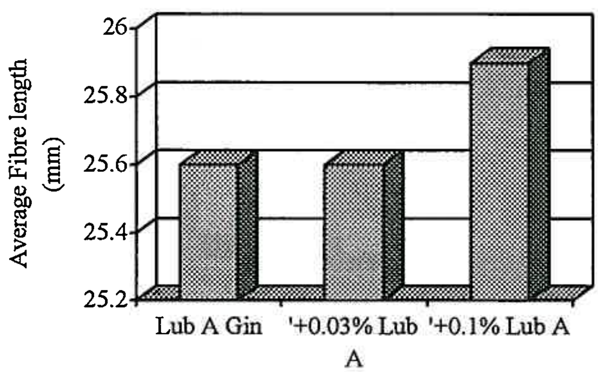


Figure 8(c). Effect of Lubricant A (added in the gin & mill) on average fibre length in card sliver

Table 4. Properties of yarn spun from lubricant treated (as per Figure 4) cotton

Treatment No.	Tenacity (cN/tex)	Elongation (%)	Evenness (CVm)	Thin (/km)	Thick (/km)	Neps (/ km)	Hairiness (Uster)	Co-Eff. of Friction
1 Control	17.39	4.47	16.73	34	85	379	5.71	0.26
2 +0.03% B	16.09	4.05	17.32	54	96	472	5.84	0.26
3 +0.1% B	16.19	3.96	18.56	70	127	547	5.75	0.26
4 +0.03% A	16.13	4.19	16.72	34	77	392	5.80	0.24
5 +0.1% A	17.59	4.32	17.25	49	98	441	5.71	0.24
6 A gin Control	16.42	4.25	16.40	27	70	192	5.73	0.24
7 +0.03% A	15.77	4.00	16.84	37	72	309	5.61	0.25
8 +0.1% A	16.24	3.94	15.69	16	51	176	5.68	0.27